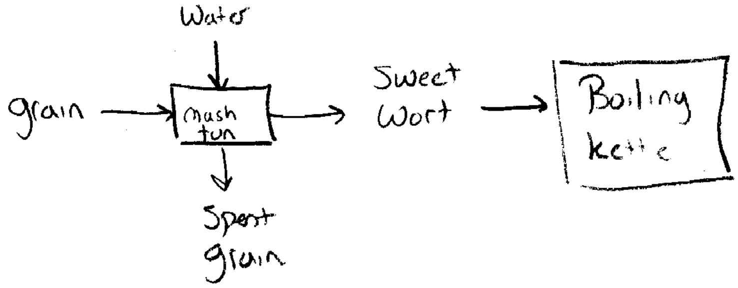
Mashing



- Mixing milled malt with water to extract starch and hydrolyze it into a fermentable sugar profile.

Grist Ratio - $\frac{\text{Mass Water}}{\text{Mass Grain}}$

→ Typical Values • 2:1 → 5:1
- 2:1 — Thick mash
- 5:1 — Thin Mash

Example: $\frac{3 \text{ lbs } H_2O}{1 \text{ lbs malt}}$

Advantages / Disadvantages

Thicker Mashes

- Improved enzymatic thermal stability
- Dextrinous wort
- more viscouse, difficulty in pumping

Thinner mashes

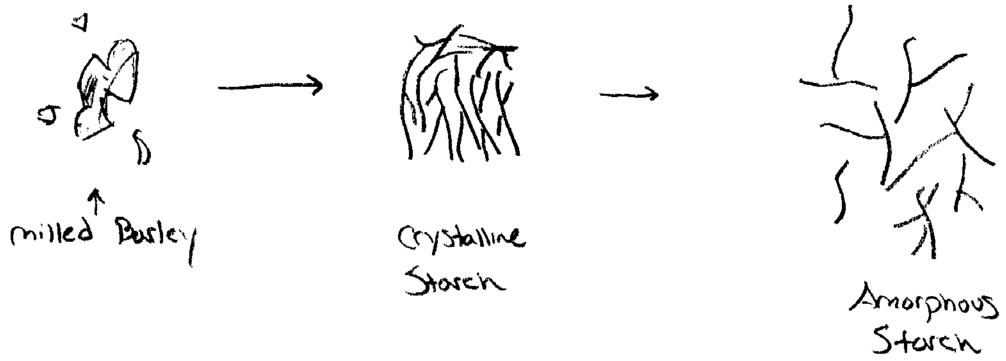
- Better extraction → (higher op)
- Faster hydrolysis
- less sparging → less tannins
- Increased thermal sensitivity

Starch Degradation - Extraction and Degradation of Starch - 2 Steps

- Gelatnization - (61 - 62°C)
- Enzymatic Hydrolysis -

Gelatinization - opening up the tightly packed endosperm

- Starch goes from tight, crystalline structure to open amorphouse one
- Allows enzymes to degrade starch to simpler oligosaccharides



<u>Enzymatic Hydrolysis</u> - enzymes cleave bonds in Starch

↓

What does Starch look like?

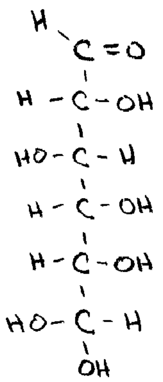
Starch Structure

2 - Types of Starch : <u>Amylose</u> & <u>Amylopectin</u>

- Amylose → Single chained Polymer
- Amylopectin → Branched chained Polymer

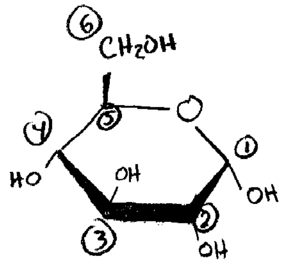
Monomer Units → <u>D - Glucose</u>

<u>D - Glucose</u>

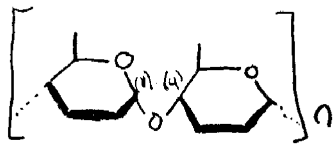


Cyclical form →

<u>α - D - Glucose</u>

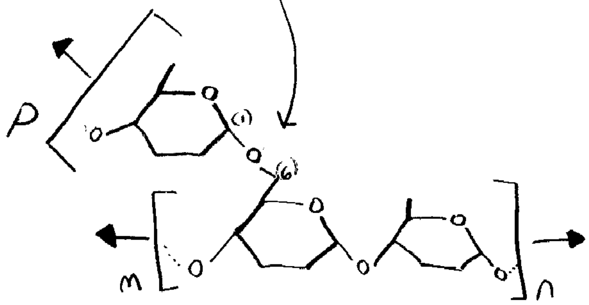


in starch →



Straight Segments : α-(1,4)- Glycosidic bonds

Branches : α-(1,6)- Glycosidic bonds



* Amylose - α(1,4) Bonds

* Amylopectin - α(1,4) and α(1,6) Bonds

Starch Degradation Products

- Fructose
- Dextrose
- Sucrose
- Maltose
- Maltotriose
- Malto tetraose
- Dextrins
- Oligo saccharides (>4 monomer units)

Fermentable — yeast will consume fermentable sugars to produce ethanol and carbon dioxide

Excess sugars and some of the smaller molecular weight Dextrins and Oligosaccharides can lead to Residual sweetness in beer.

Unfermentable — Excess unfermentable material will lead to a beer with greater body.

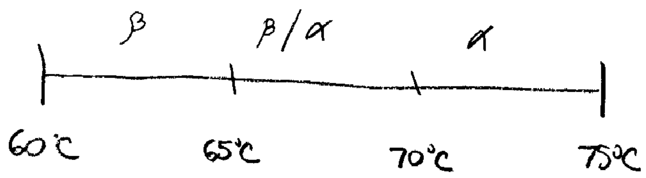
Enzymatic Activity

Starch Decomposition – (Sugar profiles) – Products see below

		Temp Range	pH
(alpha) α-amylase	→ Attacks $\alpha(1,4)$ and $\alpha(1,6)$ bonds →	70 - 75°C	5.4 - 5.8
(beta) β-amylase	→ Attacks $\alpha(1,4)$ bonds →	60 - 65°C	
limit-Dextrinase	→ Attacks $\alpha(1,6)$ bonds →		

Protein Decomposition – (lower pH, Decompose proteins)

		Temp Range	pH
endopeptidase	→ Attacks proteins, Forms free amino acids →	45-50°C	3.9 - 5.5
Carboxypeptidase	→ Attacks peptides, Forms →		4.6 - 4.8
Aminopeptidase	→ Attacks peptides, Forms →		7.0 - 7.2
dipeptidase	→ Attacks di-peptides, Forms →		8.8



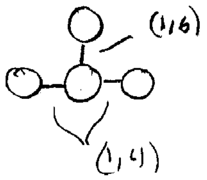
— at 78°C → Mash out

- Cease all enzymatic activity

Starch Decomposition Products

- alpha amylase attacks α(1,4) and α(1,6) bonds at random to form varying sized carbohydrates

α-amylase can only approach within one glucose monomer of an α(1,6) bond.



→ α-limit dextrin

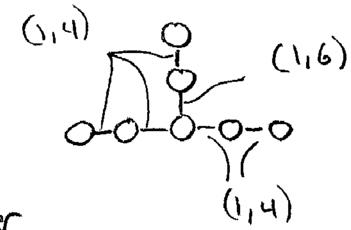
↳ Smallest sized dextrin that can form due to α-amylase

- Beta-amylase can only approach within two glucose monomer units

↓

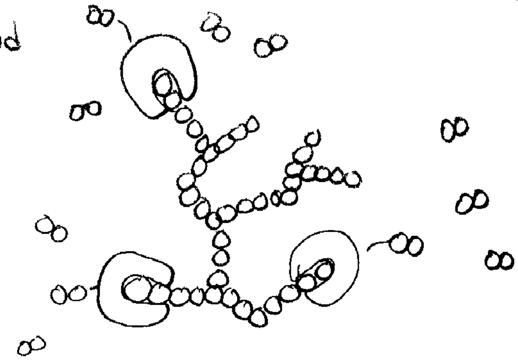
attacks α(1,4) bonds by cleaving two monomer glucose units at the end of starch molecules

"Maltose Power House"



→ β-limit dextrin

↳ Smallest sized dextrin that can form due to β-amylase



- Limit dextrinase – Cleaves α(1,6) bonds → Destroyer of Dextrins

Creates ends that alpha and beta amylase can work on

The process so far:

- Grains steeped in water
  - Gelatinization
  - Enzymatic Breakdown

→ Next: Decoction, Lautering, Sparging, Strike water

It is common to infuse the grains at one temperature to achieve a fermentable wort. Different mashing schemes exist though.

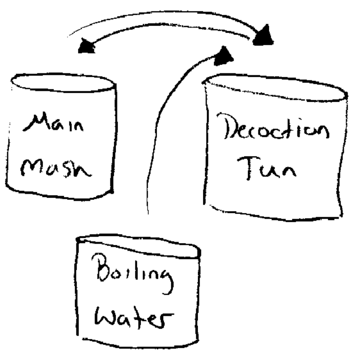
- Decoction

In decoction mashing a portion of grains are transferred from the primary mash vessel to a seperate tun. Water is added to this second tun to raise the grains to a temperature higher than first mash tun. This grain is allowed to rest for some time and then brought to a boil. The grain is then returned to the original mash tun, raising it's temperature and the process is repeated in incrementing temperatures until mash out.

Purposes:

- Convert undermodified malt → Proteins, starches, etc
- Reproducibility prior to the invention of the thermometer
- Tailor

- General Decoction Scheme



- High grist ratio quantity of grain transferred to decoction tun
  - Thicker grist = Enzyme thermostability
- Heat decoction tun to 70°C @ 1°C/min
- 15-20 min Rest → Saccharification
- Bring to Boil
- Reintroduce to mash.

Not all grains are transferred to decoction tun.

- After mashing, sweet wort is drained | Pumped to boiling kettle
  - Grains are rinsed with water to extract residual sugars → Sparging

- Sparging can be done in mash tun or spent grain can be sent to a lauter tun, which specializes in sparging.

- Sparge water temp should not exceed Mash out temp (78°C)
  - Higher temperatures can extract additional protein, husk tannins, etc.

Calculating Water Consumption/Requirements

Sparge Volume = Target Volume + Water absorbed by grain + Water lost to evaporation (Boiling) + Mash equipment losses (Dead Volume) − Mash Water Volume

- Water absorbed by grain: (80% wt spent grain)
- Water lost to evaporation (Boiling): (4-5%/hr)
- Mash equipment losses (Dead Volume): (Varies)
- Mash Water Volume: (Calculate)

Example/

A Recipe calls for:

- 11 Barrels (341 gallons) @ 20°C
- 12° P (1.048 sg)
- 79% extract (All 2-Row)
- 3% moisture
- 98% $\eta_{Brewhouse}$
- 3.75 : 1 Grist Ratio
- 1.0 hour boil time
- 5%/hr evap. losses
- 2% mash Tun Dead Volume

• Determine amounts of water needed

$$\rho_{H_2O, 20°C} = \frac{8.322 \text{ lbs}}{\text{gallon}}$$

• Target = 11 BBL

Example cont

Mash Water

$$\frac{(11\ \text{BBL})\cdot\left(\frac{258\ \text{lbs}}{\text{BBL}}\right)\cdot(1.048\ \text{sg})}{(79\%\ \text{CG})(97\%\ \text{Dry wt})(98\%\ \eta_{BH})} = 3960\ \text{lbs wort}$$

$$3960\ \text{lbs wort} \cdot \frac{12\ \text{lbs extract}}{100\ \text{lbs wort}} = 475\ \text{lbs extract}$$

[= Grain, because efficiencies calculated in previous step]

$$475\ \text{lbs grain} \cdot \frac{3.75\ \text{lbs}\ H_2O}{1\ \text{lb grain}} \cdot \frac{1\ \text{gallon}\ H_2O}{8.322\ \text{lbs}\ H_2O} \cdot \frac{1\ \text{Barrel}}{31\ \text{gallons}} = \boxed{6.90\ \text{BBL}}$$

Spent Grain

$475 \cdot (0.79)(0.97)(0.98)$

$$475\ \text{lbs Grain} - 356\ \text{lbs Actually extracted} = 119\ \text{lbs Dry grain} \cdot \frac{80\%\ \text{wet grain}}{20\%\ \text{Dry grain}} = 476\ \text{lbs}\ H_2O$$

$$476\ \text{lbs}\ H_2O \cdot \frac{1\ \text{gallon}}{8.322\ \text{lbs}\ H_2O} \cdot \frac{\text{Barrel}}{31\ \text{gallons}} = \boxed{1.84\ \text{BBL}}$$

Evap Losses

$$\frac{5\%}{\text{hr}} \cdot 1\ \text{hr} = 5\% \rightarrow 100\% - 5\% = 95\% \rightarrow \frac{11\ \text{BBL}}{95\%} - 11\ \text{BBL} = \boxed{0.58\ \text{BBL}}$$

Dead Volume

grain expansion when it swells with water ~ $\frac{1\ \text{kg Swelled Malt}}{0.7\ \text{liters}} = \frac{11.87\ \text{lbs}}{\text{gallon}}$

So a mash tun would need to be atleast:

$$\left[\left(475\ \text{lbs malt} \cdot \frac{\text{gallon}}{11.87\ \text{lbs malt (wet)}}\right) + \left(11\ \text{BBL's wort} \cdot \frac{31\ \text{gallons}}{1\ \text{BBL}}\right)\right] \cdot 2\% = \boxed{0.25\ \text{BBL}}$$

$$\text{Minimum Sparge Water} = 11 + 1.84 + 0.58 + 0.25 - 6.90 = \boxed{6.77\ \text{BBL}}$$

For greater accuracy, densities @ mash and mash out temps could be used. But estimates are okay.

(mash vol) (Spent grain)

The entire process of draining the wort from the grain and the Sparging the Spent grain is known as **Lautering**

Strike Water

Generally, grain is stored at some temperature (usually lower) than the mash temperature. There-fore, the mash water must be slightly hotter than the desired mash temp to account for the cooler grain. This temperature is the **Strike temperature**

Grain typically has about 40% the heat capacity of H_2O

To calculate:

$$\text{Strike Temp} = \left(\frac{K}{R}\right)(T_2 - T_1) + T_2$$

K = heat capacity Ratio

R = grist ratio

T_2 = Target Mash temp

T_1 = Grain Temp

Units – either use S.I. or English

SI = kg, Liters, Celsius → K = 0.41

English = lbs, Quarts, Fahrenheit → K = 0.20

* K changes depending on Convention

** Grist Ratios must be converted to $\left[\frac{\text{Volume } H_2O}{\text{Mass Malt}}\right]$

example/ Target Mash = 68°C

R = 4.17 liters/kg malt

Grain Temp = 30°C

$$S.T. = \left(\frac{0.41}{4.17}\right)(68°C - 30°C) + 68°C$$

$$= \boxed{71.7°C}$$